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A high resolution daily gridded rainfall dataset (1971–2005) for mesoscale meteorological studies

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In this communication, we discuss the development of a very high resolution (0.5° × 0.5°) daily rainfall dataset for mesoscale meteorological studies over the Indian region. The dataset was developed using quality-controlled rainfall data from more than 3000 rain gauge stations over India. The analysis consists of daily rainfall data for all the seasons for the period 1971–2005. A well-tested interpolation method (Shepard's method) was used to interpolate the station data into regular grids of 0.5° × 0.5° lat. × long. After proper validation, it has been found that the present dataset is better compared to other available datasets. A few case studies have been shown to demonstrate the utility of the dataset for different mesoscale meteorological analyses. However, since the data density is not kept uniform, there is a possibility of temporal inhomogeneity and therefore, the present dataset cannot be used for trend analysis. The dataset is freely available from the India Meteorological Department, Pune.

Keywords: Mesoscale meteorological studies, rainfall dataset, rain gauge.

INFORMATION on spatial and temporal variations of rainfall is important in understanding the hydrological balance on regional scale and water management in agriculture, power generation and drought management. High resolution gridded rainfall data are required to validate regional and mesoscale models and to study the intra-seasonal fluctuations. In recent years, there has been considerable interest in developing high-resolution gridded datasets[1–5]. Rajeevan *et al.*[4] developed a high resolution (1° × 1° lat. × long.) daily rainfall dataset for the period 1951–2004, which is being used in various studies[6,7]. However, there have been demands for much higher resolution (say 50 km × 50 km) for mesoscale rainfall analysis and mesoscale meteorological applications.

To meet the requirements of the research community, an initiative was taken up at the National Climate Centre, India Meteorological Department (IMD), Pune to develop a high resolution (50 km spatial resolution) dataset for mescoscale applications using daily rainfall data archived at IMD. In this study, we discuss the development of the high resolution daily gridded rainfall dataset using rain-

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fall data from more than 6000 stations for the period 1971–2005.

For the present analysis, daily rainfall data archived at the National Data Centre, IMD, Pune for the period 1971–2005 have been used. Standard quality controls have been performed before carrying out the analysis. The precipitation data themselves are checked for coding and typing errors. Many such errors were identified, which were corrected by referring to the original manuscripts. These are daily 24 h accumulated rainfall ending at 0300 UTC (0830 h IST). For the period of analysis, IMD had rainfall records of 6076 stations with varying periods. In the gridded rainfall dataset developed by Rajeevan *et al.*[4], rainfall data of only 2140 stations were used to minimize the risk of generating temporal inhomogeneities in the gridded data due to varying station densities. However, for the present analysis, we have used all the available stations for interpolating into regular grids. There were about 3500 stations on an average for the daily analysis. However, the data density varied from year to year. The network of stations considered for the rainfall analysis is shown in Figure 1 *a*. The data density is not uniform; however, there are many stations from South India. The daily variation in the number of stations used for the analysis is shown in Figure 1 *b*. The data density is more or less satisfactory and uniform till 2004. Data for the year 2005 are however sparse. Since the data density is not kept uniform, there is a possibility of temporal inhomogeneity and therefore, the present analysis cannot be used for trend analysis as done by Goswami *et al.*[6]. However, the dataset is useful for many other mesoscale meteorological studies as discussed here.

There are many methods of numerical interpolation of irregularly distributed data to a regular *N*-dimensional array. Bussieres and Hogg[8] studied the error of spatial interpolation using four different objective methods. For application to the specific project grid, the statistical optimal interpolation technique displayed the lowest root mean square errors. This technique and Shepard OA displayed zero bias and would be useful for areal average computations. New *et al.*[1] used the thin plate splines for interpolation. Mitra *et al*.[2] used the successive correction method of Cressman for merging satellite-derived rainfall data and station data.

For the present analysis, as in Rajeevan *et al*.[4], we have used the interpolation scheme proposed by Shepard[9]. In this method, interpolated values are computed from a weighted sum of the observations. Given a grid point, the search distance is defined as the distance from this point to a given station. The interpolation is restricted to the radius of influence. For search distances equal to or greater than the radius of influence, the grid point value is assigned a missing code when there are no stations located within this distance. In this method, interpolation is limited to the radius of influence. A predetermined maximum value limits the number of datapoints used, which, in the case of high data density, reduces the effective radius of influence. We have also considered the method proposed by Shepard[9] to locally modify the scheme for including the directional effects and barriers. In this interpolations method, no initial guess is required.

We have interpolated station rainfall data into a rectangle grid (69×65) for each day for the period 1971–2005. The starting point of the grid is 6.5°N and 66.5°E. From this point, there are 69 datapoints towards east and 65 datapoints towards north. We have created one binary file for each year. For the leap year, we have created data for 366 days.

We further examined the quality of the developed $0.5° \times 0.5°$ daily rainfall dataset. Figure 2 *a* and *b* shows the spatial variation of mean rainfall during the southwest

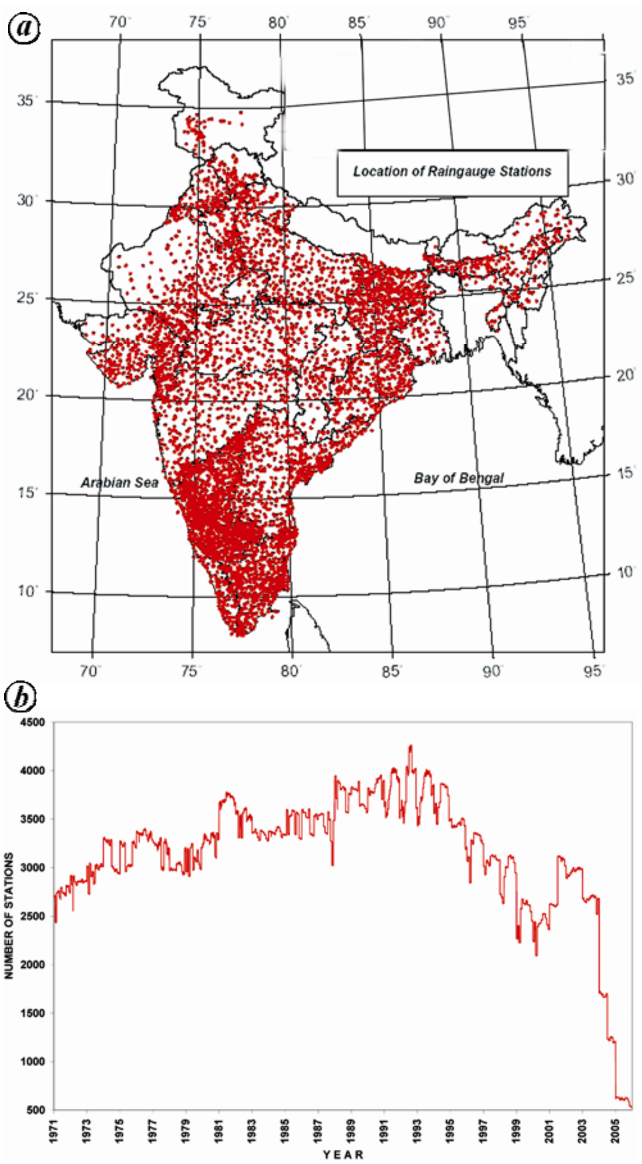

Figure 1. ***a***, Location of rain gauge stations used in the analysis. ***b***, Time series of total number of stations used for rainfall analysis per day for the period 1971–2005.

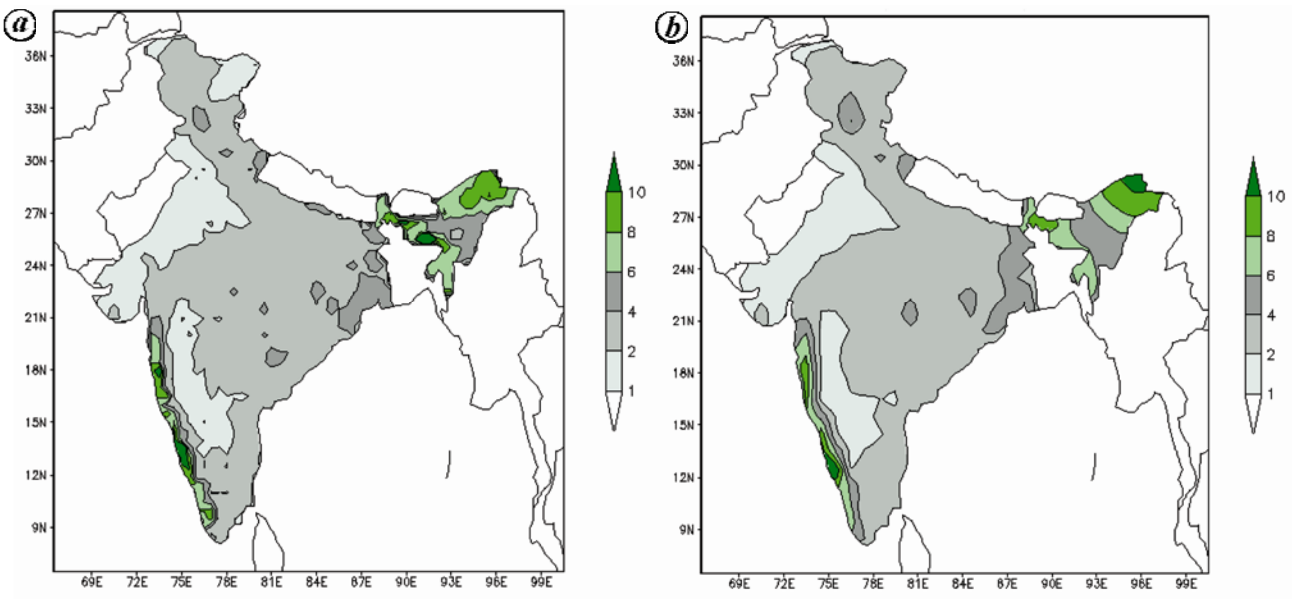

Figure 2. Mean annual rainfall (mm/day) using (***a***) the present 0.5° analysis and (***b***) the 1.0° analysis of Rajeevan *et al*.[4].

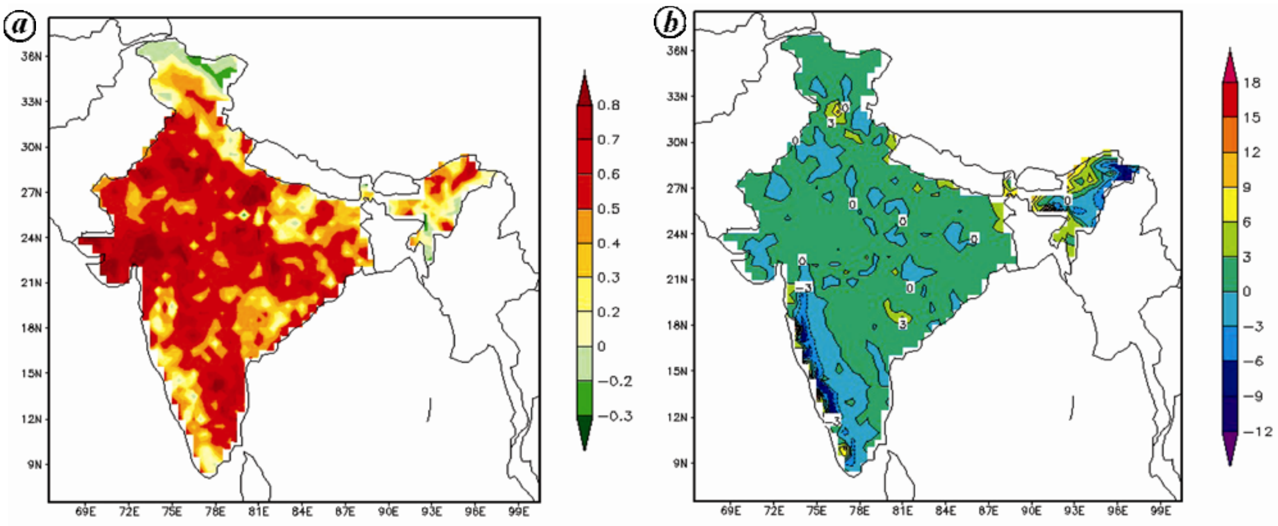

Figure 3. ***a***, Spatial pattern of correlation between the seasonal rainfall (June to September) from the present IMD rainfall analysis and the APHRODITE analysis for the period 1980–2002. ***b***, Spatial pattern of the differences (mm/day) between the seasonal rainfall (June to September) from the IMD rainfall analysis and the APHRODITE analysis for the period 1980–2002.

monsoon (June to September) calculated from the present dataset and the 1° × 1° rainfall dataset[4] respectively. The mean rainfall pattern shows a maximum along the west coast and over NE India. Another rainfall maximum is observed over the east Central parts of India. In comparison, the dataset developed in this study with 0.5° resolution shows more realistic spatial variation of mean rainfall with finer details of spatial variation. In the mean rainfall pattern with 0.5° resolution data, the rainfall maximum around Cherrapunji is clearly observed.

Recently, another high resolution rainfall dataset was developed at the Research Institute for Humanity and Nature (RIHN). The project is named as the Asian Precipitation-Highly Resolved Observational Data Integration Towards Evaluation of the Water Resources (APHRODITE). Under this project a high resolution (0.25° × 0.25°, and 0.5° × 0.5°) daily rainfall dataset was developed for the Asian region. The basic algorithm adopted here is based on Xie *et al*.[5]. The details of the project and the dataset are discussed elswhere[3]. The daily APHRODITE dataset is available at http://www.chikyu.ac.jp/precip/. The dataset consists of 0.5° × 0.5° gridded daily rainfall for the period 1980–2002. We have compared the present rainfall analysis with the dataset developed under the APHRODITE project. Figure 3 *a* shows the correlation coefficient between the SW

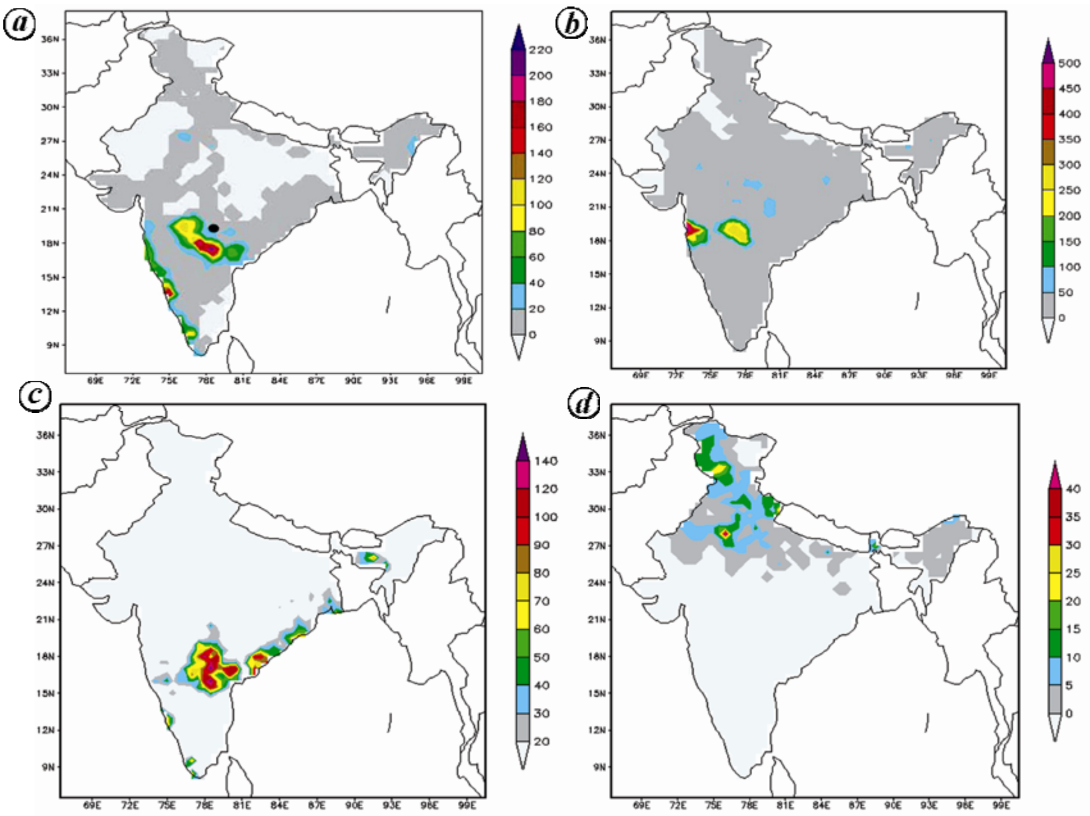

Figure 4. Case studies using the IMD 0.5° rainfall analysis. ***a***, Rainfall due to the monsoon depression on 24 August 2000. ***b***, Heavy rainfall over Mumbai on 27 July 2005. ***c***, Rainfall due to the tropical cyclone on 6 October 1994. ***d***, Rainfall due to a winter western disturbance on 31 January 2003. Note the difference in the rainfall scales.

monsoon seasonal rainfall derived from the present analysis (IMD analysis) and the APHRODITE analysis. The correlation coefficient is high (exceeding 0.6) over central and NW India. The correlations are, however, low along the west coast of India and over some parts of NE India. The differences of the SW seasonal rainfall between the two datasets are shown in Figure 3 *b*. The APHRODITE analysis underestimates the rainfall maximum along the west coast and NE India. Otherwise, the differences are mostly within 3 mm/day over the country. The basic difference between the two datasets is the total number of stations used in the rainfall analysis. While IMD analysis used more than 6000 stations as mentioned above, the APHRODITE analysis used on an average only 2000 stations. However, the APHRODITE analysis could also capture the large-scale features of monsoon rainfall over the Indian region.

The present IMD rainfall analysis dataset can be used for several mesoscale applications. Here, we consider the rainfall analysis associated with some important weather situations. Figure 4 shows the daily rainfall maps pertaining to the case studies considered. The first case pertains to the rainfall analysis of 24 August 2000, showing the rainfall distribution associated with the monsoon depression which formed over the Bay of Bengal and moved northwestwards. The centre of the depression is also shown. The maximum rainfall over the SW sector of the monsoon depression is well captured in the rainfall analysis. The second case pertains to the disastrous heavy rainfall event that occurred over Mumbai[10,11] on 26/27 July 2005. The rainfall map clearly shows intense heavy precipitation exceeding 50 cm around Mumbai city. It may be mentioned that on 26/27 July 2005, intense rainfall occurred over a small area less than 2500 km^2 over Mumbai[10]. The third example is heavy rainfall associated with the passage of a tropical cyclonic storm which crossed the Andhra Coast on 6 October 1994. The last example is rainfall over NW India, associated with the passage of a winter western disturbance across the northern parts of the country on 31 January 2003. These examples are indicative of many useful applications of the present rainfall analysis.

The present dataset is freely available for research from the National Climate Centre, IMD, Pune. Further details can be found at the centre's website: ncc@imdpune.gov.in

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Properties of cloud base height during southwest monsoon period over a tropical station, Thiruvananthapuram

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The study of the clouds and their properties has remained unexplored, especially during the southwest (SW) monsoon season due to the unavailability of reliable data sets. Here we made an attempt to study the cloud base height (CBH) and its characteristics during the SW monsoon period of 2007 using CBH data obtained by a Vaisala Laser Ceilometer (VLC). The VLC was made operational at Thiruvananthapuram since July 2006 to monitor the CBH every 15 s. The relation of CBH with meteorological parameters is studied using the radiosonde observations. We found that clouds during the SW monsoon season have mainly concentrated below 2500 m. A layer with relatively void clouds was present between 2500 and 4000 m. We call this region as cloud-free zone. The amplitude of variability of CBH was less compared to the variability of the cloud frequency. Active monsoon is when the cloud frequency exceeds 70% and break phase is when it is less than 40%. The cloud frequency increases when the wind shear increases in the lower levels. Similarly, temperature is more during break phase of monsoon however, the relative humidity shows an increase during active phase of monsoon. Multiple clouds were also noticed during active phase, but it was negligible during break phases of monsoon.

Keywords: Ceilometer, cloud base height, cloud frequency, southwest monsoon.

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THE Indian summer monsoon occurs from June through September as a global phenomenon and is caused by the large convective heat source on the ITCZ (Inter Tropical Convergence Zone) in the northern hemisphere tropics, extending from the Arabian Sea to the West Pacific Ocean. The convective heat source lasts for more than one hundred days. During these convective periods, organized cloud bands are formed over the Indian subcontinent. Studies of these clouds are important in a country like India with vast arable land and with nearly 58% of the population involved in agriculture, directly and indirectly. Agriculture depends primarily on monsoon rainfall for much of its water needs. Clouds that are seen during the southwest (SW) monsoon season are considered to be of different types: stratiform and cumuliform clouds[1]. In this perspective, understanding the characteristics of clouds in this region during the season is pertinent.

Clouds and their associated microphysical properties strongly regulate the radiative transfer and hydrological cycle. Clouds especially during the SW monsoon season have understandably important effects on planetary and surface radiation budgets and water cycles of the earth, thus playing a key role in regulating the earth's climate and climate variability[2]. Different types of clouds have varying effects on the atmosphere[3]. Clouds in the tropical atmosphere occur in a wide range of sizes, starting from isolated cumulus to large cloud clusters. The large cloud clusters exhibit mesoscale organization and account for most of the rainfall and vertical transport of energy from the atmospheric boundary layer (ABL) to the upper troposphere[4]. The advent of satellites provides a great advantage to study cloud properties like cloud cover[5,6], liquid water path[7]. Recently, information concerning ice-